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JAN 81 A J MENDELSON, R NORMANDIN

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A microwave-pumped XeCl* laser

A. J. Mendelsohn, R. Normandin, S. E. Harris, and J. F. Young
Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305

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A XeCl* excimer laser excited by 2- μ s-long, 9.375-GHz microwave pulses has been constructed. Spontaneous emission times of ~ 500 ns have been observed, while the maximum laser pulse length was 100 ns. The laser pulse length appears to be limited by the buildup of a transient loss.

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We have constructed a long-pulse 308-nm XeCl* excimer laser excited by high-power microwave (9.375 GHz) pulses. Electron-beam, avalanche-discharge, and electron-beam-sustained discharge pumped excimer lasers have been studied extensively¹⁻⁴ and each have different advantages and limitations. Microwave pumping retains the practical simplicity of the avalanche discharge, while avoiding its extreme sensitivity to discharge conditions. The pulse length and efficiency of avalanche-discharge lasers are limited by the formation of plasma arcs, which make it impossible to maintain adequate excitation rates throughout the volume. The sensitivity to such factors as detailed gas composition, electrode irregularities, degree and uniformity of preionization, and the characteristics of the driving source have been described in detail by Levatter and Lin.⁵ They note that, except for their own work⁶ using high-power x-ray preionization and very fast rise-time drivers, avalanche-discharge laser pulse lengths have been limited to about 10 ns.

In contrast, microwave excitation of high-pressure gases is much less sensitive to the details of the plasma: the

power deposition is nominally independent of gas composition, uniform preionization is not critical, and even a local breakdown or arc does not prevent effective excitation in other regions of the plasma. In addition, the device is easily constructed with high-vacuum, halogen-compatible materials. As a result, we have been able to observe spontaneous XeCl* emission for periods of up to 500 ns and to produce 100-ns laser pulses using a very simple apparatus.

A Varian SFD-303 coaxial magnetron and line-type pulser provides 600-kW, 2- μ s-long pulses at 9.375 GHz. The pulses have a rise time of about 100 ns and travel through ~ 8 m of x-band waveguide pressurized with SF₆ to the active laser region, illustrated in Fig. 1. The microwave energy is coupled from the primary guide into a secondary guide containing a concentric 3-mm i.d. quartz tube holding the laser gas mixture. The gas mixture is slowly recirculated through an all-stainless-steel closed loop system. Although the magnetron is capable of 400-Hz operation, thermal shock effects combined with our slow flow rates limited operation to 10 Hz. In addition, the recirculating pump limits absolute pres-

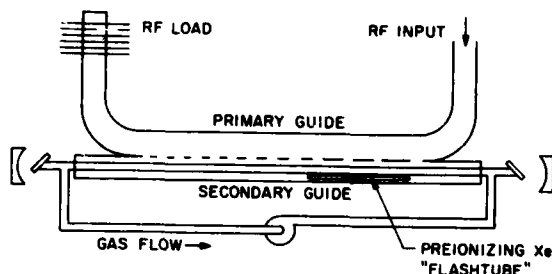


FIG. 1. Schematic of the microwave-pumped XeCl^* laser. The Brewster windows are CaF_2 and the cavity consists of 2-m-radius mirrors 1 m apart.

tures to about 2 atm.

The microwave coupler consists of a series of "Riblet Tee" slots,⁷ which are spaced to provide nearly uniform transfer of microwave energy from the primary to secondary waveguide along the 40-cm-long coupling region. Using this coupler, 80–90% of the energy in the primary guide can be absorbed in a variety of rare-gas-halogen-buffer gas mixtures at pressures between 1 and 3 atm, yielding a power deposition of $(1-2) \times 10^5 \text{ W/cm}^3$. Once the discharge is initiated the power reflected to the source is insignificant.

The microwave discharge is more stable and reproducible if it is initiated by a small amount of preionization. This is accomplished by placing a ~ 12 -cm-long sealed quartz tube containing ~ 1 Torr of Xe in the secondary guide. This low-pressure Xe "flash lamp" breaks down early in the microwave pulse providing simple, self-timed UV preionization of the laser mixture.

Laser action in XeCl^* was observed at several wavelengths centered at 308 nm. The net round-trip gain was just over 20% using a mixture consisting of 0.3% Xe, 0.05% HCl, and 99.6% Ne at a total pressure of 2 atm. Figure 2 shows the relative time behavior of the microwave, sponta-

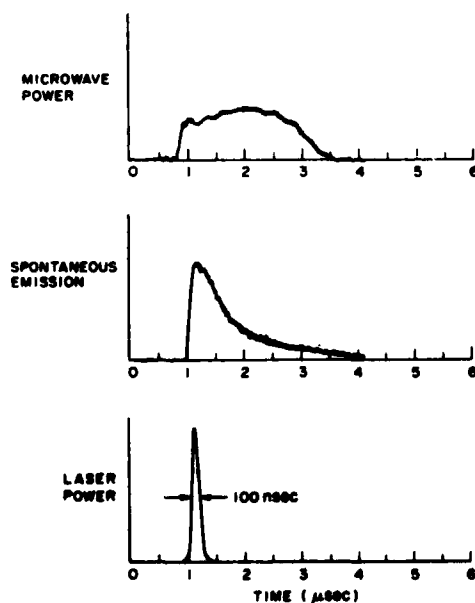


FIG. 2. Relative time behavior of the microwave power, XeCl^* spontaneous emission, and laser pulses.

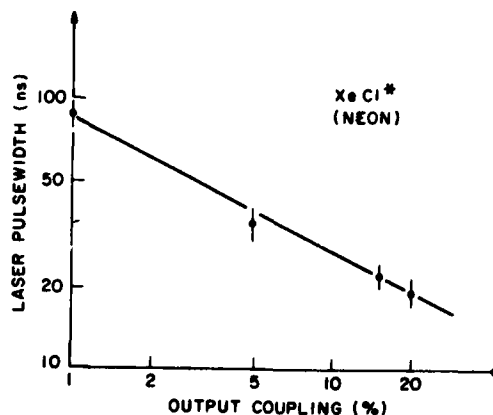


FIG. 3. Laser pulse width vs output coupling, log-log scales.

neous fluorescence, and laser pulses. The laser pulse length had a maximum value of 100 ns and was inversely proportional to the output coupling (Fig. 3), while the spontaneous emission lasted for over 500 ns. It seems likely that the pulse length was limited by a transient loss which built up during the pulse.⁸ Our optimum gas mixture corresponds closely to the one given in Ref. 8, which minimizes such transient losses, while it differs considerably from the mixtures normally used for avalanche-discharge lasers.

The peak laser output power was only $\sim 20 \text{ W}$ with 5% output coupling, giving an overall efficiency of less than 0.01%. In the present design, however, the efficiency is significantly reduced by the small fraction of the discharge volume which is used by the laser mode. A more useful figure is the formation efficiency, defined as the ratio of the energy stored in the XeCl^* exciplex to the input microwave energy. Using the measured 20% gain and the stimulated cross section for XeCl^* , this is calculated to be 0.2%. The spontaneous-emission intensity increases with microwave input power and total pressure as shown in Fig. 4, indicating a potential for higher power and efficiency.

We have demonstrated that microwave pumping is a simple technique for producing relatively long pulse excimer

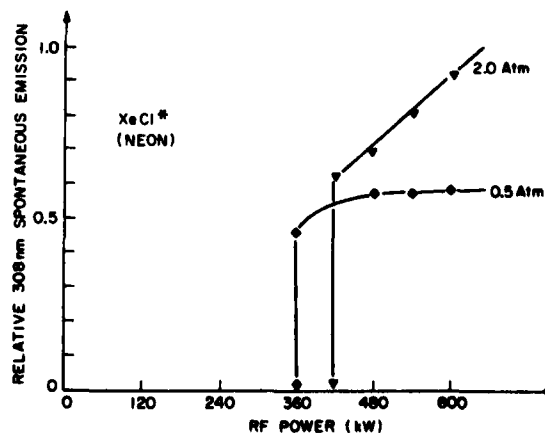


FIG. 4. Intensity of 308-nm spontaneous emission as a function of microwave power and total pressure.

lasers. Such a system may be useful for generating well-controlled mode-locked pulses for a high-power amplifier chain. In addition, the microwave pumping scheme lends itself to applications where long gas lifetimes and hands-off operation are required because of the all metal and quartz construction and the absence of electrodes with their sputtering problems.

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